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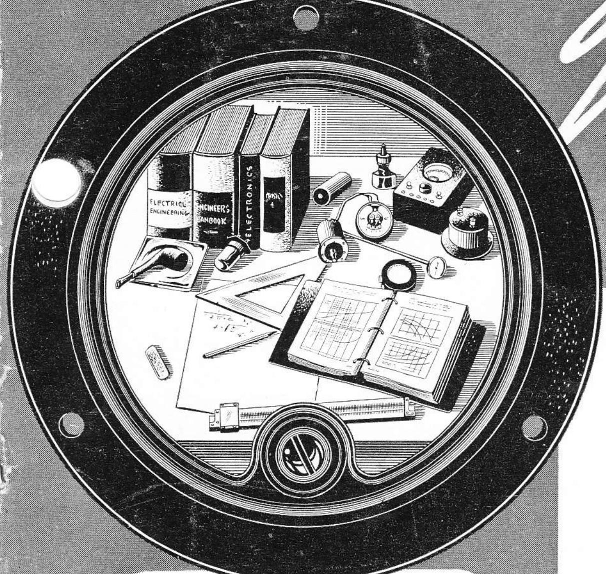

In This Issue

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THE WESTON MASTER II UNIVERSAL PHOTOGRAPHIC EXPOSURE METER

THE Weston Master II Exposure Meter is the culmination of thirteen years' experience in the design of photographic exposure meters combined with fifty years of instrument design. See

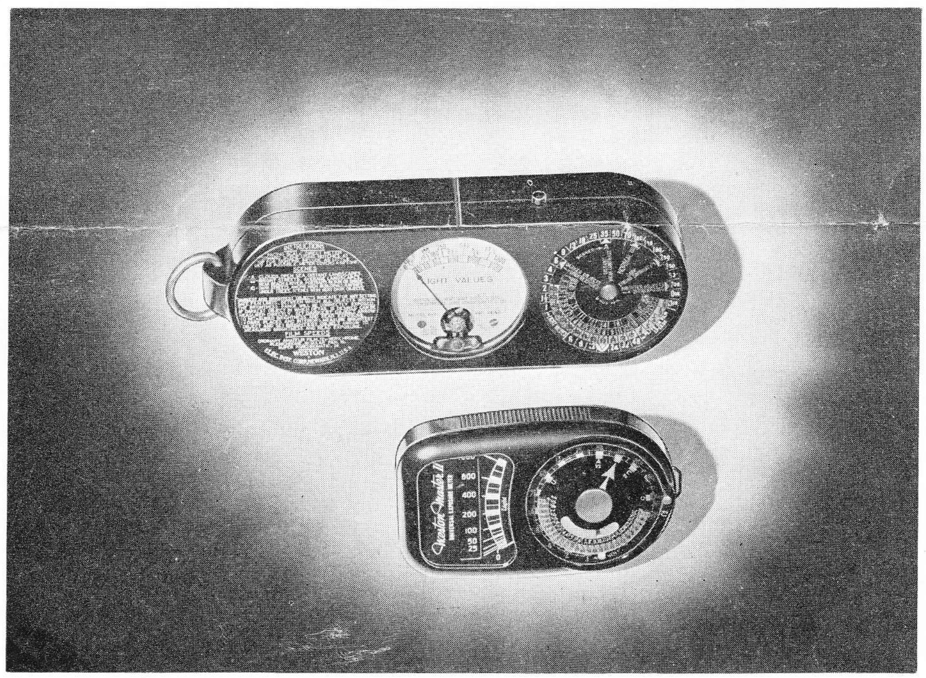


Figure 1—Thirteen years' experience in engineering and design of exposure meters is well illustrated in the above comparison of the first Weston model (top), introduced in 1933, and the present Master II.

Figure 1. In the belief that many engineers and physicists are also photographers, a brief discussion of the engineering background of photographic exposure and the design of the meter may be of interest. Meter size, design details, and the quality of workmanship are of course very important but, for the purpose of brevity, only the salient or technical features will be covered in this article.

Basically, the exposure meter consists of a brightness meter calibrated in "candles per square foot" and a calculator by means of which the brightness readings are converted into photographic exposure according to the following relationship:

$$\frac{t}{f^2} = \frac{0.8}{WB}$$

where

t = time of exposure in seconds

f = camera aperture

W = Weston rating of the film or plate being used

B = brightness in candles per square foot.

The first Weston exposure me-

ter was designed and marketed in 1933. At that time, several systems of rating films existed but were not considered satisfactory and a new and unique scheme of film rating was devised which was and still is called the Weston Film

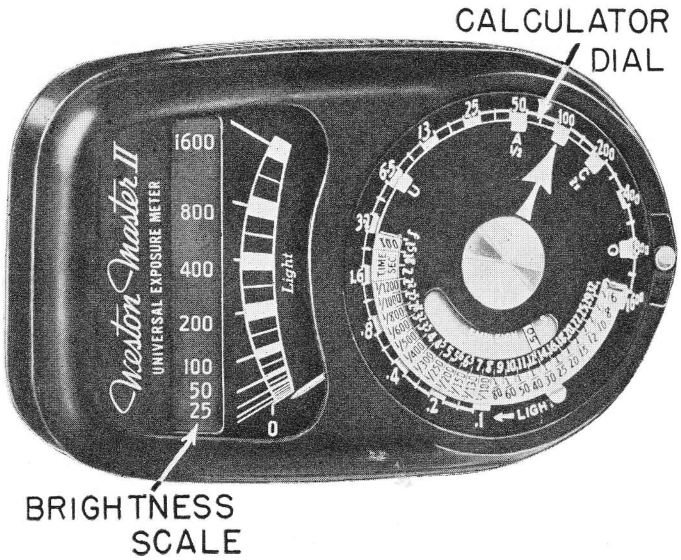


Figure 2—Head-on view of the Master II showing the high range of the brightness meter and the exposure guide dial.

Speed Rating. A great deal of literature has been published on the subject of film speeds, but for the purpose of this article it should be sufficient to state that with the advent of the Weston exposure meter and the Weston film ratings, the photographer for the first time was able to approach the problem of exposure in a scientific manner.

Criterion of Photographic Exposure

From the first, Weston exposure meters were designed to measure brightness as it was believed that the correct criterion of exposure is the scene brightness. Numerous articles have been written on the subject of Incident and Reflected Light as the criterion of photographic exposure. The proponents of the incident light system measure the illumination falling upon the object or scene while the proponents of the reflected light system measure the brightness of the object or scene. Good theoretical arguments can be advanced for both systems, but the theory behind the reflected light system, backed by a very extensive amount of field work and a statistical study of the resulting negatives, shows a preponderant advantage in favor of the reflected light system. The majority of the exposure meters on the market follow this principle in spite of the higher cost in building reflected light meters over incident light meters, indicating that the weight of opinion among the amateur and professional photographers supports this viewpoint.

Figure 2 shows the Model 735 Weston Master II Universal Meter. Perhaps a few of the salient design features may be of interest and these are described briefly below:

THE PHOTOELECTRIC CELL used in the Weston Master II is a barrier-layer (dry disc) type of cell which has the property of converting light energy into electrical energy and since there is a definite relationship between the light on the photoelectric cell and the current obtained from it the microammeter can be calibrated directly in brightness or candles per square foot. The quantity of light which strikes the cell is dependent upon the scene brightness and the acceptance angle of the meter.

The spectral characteristics of the cell are very favorable to the design of an exposure meter because of the relatively high response to the blue end of the spectrum to which most photographic films have their maximum sensitivity.

THE MICROAMMETER has been especially designed so that the scale, although calibrated in brightness or candles per square foot, is proportional to photographic exposure. The problem of design is quite similar to the design of db meters used in the radio and communications field as both the photographic increments and db increments progress logarithmically or on the basis of a constant increment between steps. The average microammeter in the Master II requires 100 microamps for 60 degrees or full scale deflection, approximately 25 microamperes for half-scale deflection and

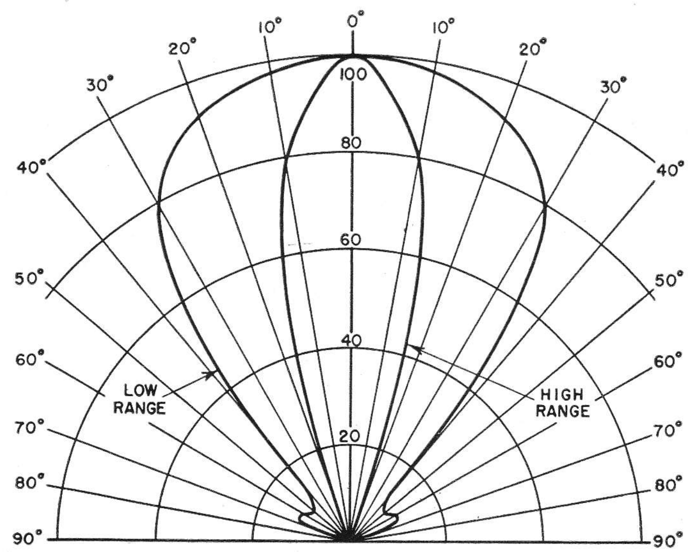


Figure 3—Acceptance angle curves showing relative response of meter to light from various angles.

because of this logarithmic response the microampere sensitivity at the lower end of the scale is extremely high for a portable meter of this size. If electric power were purchased at five cents a kilowatt hour the microammeter in the Master II could be made to deflect back and forth continuously from zero to top mark for 47,000 years at a cost of one cent.

The current necessary to operate the microammeter is obtained directly from the photoelectric cell.

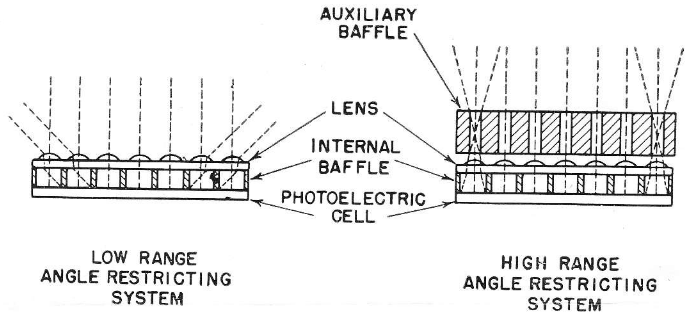
THE ACCEPTANCE ANGLES of the low and high ranges of the Master II meter are shown in Figure 3. Obviously, the greater the acceptance angle the more light energy the photocell will receive from a given scene. But the acceptance angle of the lens in an average camera is rarely over 50°. Assuming other design factors as being constant, it can be stated that the cost of building an exposure meter is governed to a very large extent by the acceptance angle as a smaller acceptance angle necessitates greater microammeter sensitivity which in turn means finer windings on the movable coils, lower spring torques, much more careful inspection of pivots and jewels and greater operator skill in the overall assembly. The consensus of opinion is that the acceptance angle of an exposure meter should be at least as small as that of the camera being used.

It will be seen in Figure 3 that the high range acceptance angle is considerably smaller than most camera lenses and this high selectivity has proved to be a real advantage in outdoor photography. The low range acceptance angle is greater than most camera lenses and this large acceptance angle has been chosen as a means of obtaining sensitivity to low brightness levels. This sacrifice in acceptance angle to obtain sensitivity is predicated on the fact that where low brightness levels are encountered, such as indoor photography, it is possible to take close-up readings and thus cancel out the effect of the large acceptance angle and gain the advantage of being able to measure low brightness levels.

Method of Controlling Acceptance Angle

Figure 4 shows the angle restricting methods used for the low and high ranges of the Weston Master II meter. The low range contains an internal baffle consisting of laminated plates having hexagon holes and each hole is covered by the individual lens of a multiple lens plate. The internal baffle, which is painted dull black, absorbs the oblique light and therefore, prevents it from reaching the photoelectric cell. The lenses over the internal baffle have their outer surfaces convex so that light received by the meter from areas off of normal incidence are still at normal incidence to the lens surface thus minimizing surface losses. This is shown by the polar curve in Figure 3 wherein it will be seen that the acceptance angle curve is quite flat over an appreciable angle. The high range acceptance angle is controlled by means of a plate of appreciable thickness having holes which have a high ratio of depth to diameter which forms a mechanical light baffle. Because this is a strictly mechanical light restricting means it is quite selective to normal incident light as can be seen in Figure 4.

Figure 4—Arrangement of light restricting means to control acceptance angle.



THE BRIGHTNESS METER is a combination of the photoelectric cell, the microammeter and the light baffles and as such is calibrated in candles per square foot. The relationship between brightness and illumination for a perfect diffusing surface may be expressed by the following equation:

$$B = \frac{RI}{\pi}$$

where

B = brightness in candles per square foot

R = reflection factor of the diffusing surface

I = illumination in foot candles.

It will be noted that the scales on the brightness meter are calibrated to be proportional to exposure values although the scale is direct reading in actual candles per square foot. If this were not so, then a change in brightness from 1600 to 800 would represent ½ of full scale deflection on the meter but only three small divisions on the calculator, and the balance of readability between the meter scale and the calculator would be extremely poor. Calibration proportional to exposure values results in the best possible correlation between the meter indications of brightness and the calculator values in terms of photographic exposure.

Although the brightness meter has been designed primarily for photographic purposes it will be found useful for measuring the brightness of other objects such as cathode ray tubes as used in television apparatus, the brightness of luminaires, etc. When using the meter it will be noted that the intermediate scale values are not marked, but these values can readily be calculated since the scale increments are in steps of the cube root of two; hence each succeeding scale value is 1.26 times the brightness of the preceding scale value.

THE CALCULATOR: After the brightness of the object or scene to be photographed has been measured by the brightness meter it is necessary to translate this value into photographic exposure values, taking into account, at the same time, the photographic sensitivity or Weston Film Speed Rating of the film or plate being used in the camera. This is done by simply setting the film speed dial to the applicable Weston Film Speed value, and then by setting the large arrow on the top calculator dial to the brightness value corresponding to the reading obtained on the brightness meter. After these settings have been made there is a definite alignment of the f/stop scale and the exposure time scale and each combination gives exactly the same photographic exposure. The choice of a combination is a matter of photographic judgment. For example, if a picture is being taken of a moving object, the photographer may decide that 1/100 second is necessary in order to prevent blurring on the negative and in this case the f/stop aligned with 1/100 second is taken from the calculator. If, however, the picture is to be of a landscape, then depth of focus is the important consideration and the photographer may decide that the lens should be stopped down to f/22 and in this case exposure time aligned with f/22 is taken from the calculator.

The use of the large or normal arrow places that part of the scene, having a brightness corresponding to the meter reading, at the center of the density-exposure characteristic curve of the film and in the case of black-and-white film the U and O positions of the calculator indicate the minimum and maximum brightness scene values for which the film will still show details. For the serious photographer, who desires to obtain the best possible results, the use of the U, O, A and C positions on the calculator allow him to correlate his exposure data to the film characteristics.

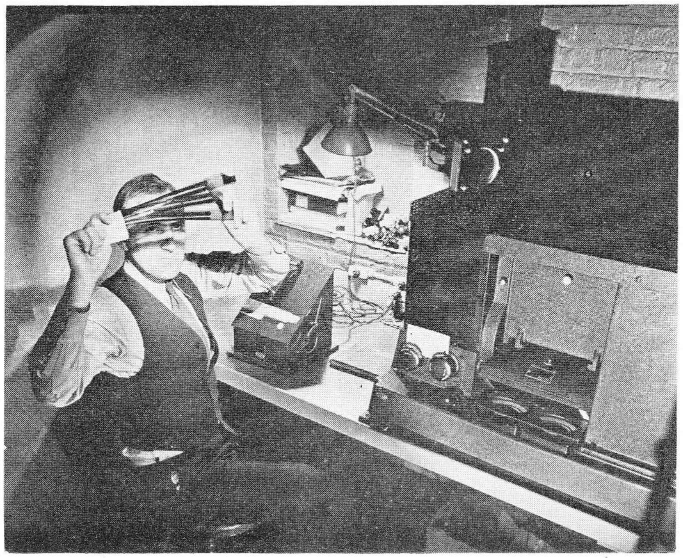


Figure 5 — Examining the double track of exposed film which the Sensitometer, shown at the right, has left on three samples of film.

It was previously explained that the brightness meter had uniform divisions in terms of exposure. In order to obtain the optimum correlation between the meter and the calculator the latter is also designed to have uniform divisions in terms of photographic exposure. Because of this geometric progression both the brightness meter and the calculator cover a tremendous range and still in all cases the increments are on a uniform percentage basis. The table below shows the ranges covered.

	Range	Ratio of Values
Brightness	0.1 to 1600	1:16000
f/stops	1.5 to 32	*1:455
Film Speeds	0.3 to 800	1:2667
Exposure Time	1/1200 to 100	1:120,000

**Ratio of f/stops is based upon the square of the f/stops as the aperture is inversely proportional to the square of the f/stop values.*

Weston Film Speed Values

The Weston Electrical Instrument Corporation maintains a Sensitometric Photographic Laboratory in which all types and makes of films are periodically tested. See Figures 5 & 6. In addition to the tests made in the laboratory camera tests are made in the field. Film is purchased over-the-counter from various stores throughout the States and processed exactly in accordance with the manufacturers' recommendations. From the density-exposure characteristic and camera tests of each brand of film tested, the Weston Film Speed is determined, and from time to time "Speed sheets" are made available listing the Weston Film Ratings of all brands of film in common use. By following this procedure, the professional and amateur photographers are assured of the best possible

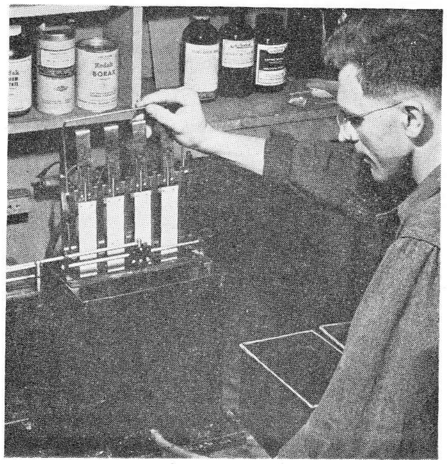


Figure 6 — A special developing tank with constant agitation assures correct development.

Weston Film Rating which, when used with their Master II, will result in the best possible photographic exposure.

E. N.—No. 15 —*A. T. Williams*

A VARIABLE RATIO CURRENT TRANSFORMER

The basic contents of this article appeared in the August 1946 issue of PRODUCT ENGINEERING and have been reworked by the author for publication in Weston Engineering Notes.

ELECTRICALLY driven machine tools are being equipped in increasing numbers with

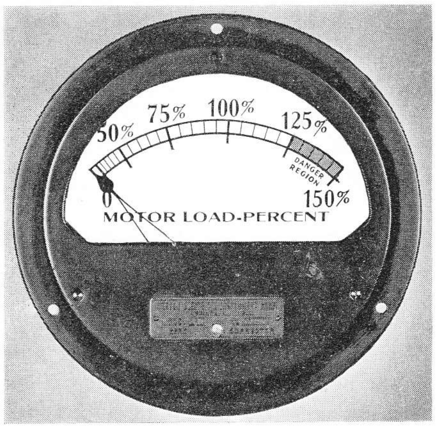


Figure 1—For simplicity in using a single instrument as a load indicator, scales are usually marked in percentages.

built-in ammeters or wattmeters to both help the operator maintain rated capacity and, at the same time, to reduce motor burnouts by indicating overloading. When several motors are integrated into a single machine tool, such instruments are especially valuable in helping the operator maintain the best individual loads for overall optimum production.

In the application of an ammeter or a wattmeter to a machine tool having a given size motor, there is the problem of the meter rating as the power line voltage and phase change. A five hp motor requires a different number of amperes at full load if single phase than if two or three phase. Voltages may be 230, 460, or 575 volts, the current for constant horsepower decreasing as the voltages increase. And at 25 and 60 cycles the current ratings will differ, other things being equal. Thus, the meter ratings vary practically as much as the variation in motor specifications, even for the same horsepower, and there is the continual problem of stocks of meters of suitable ranges.

To meet this problem Weston has worked out a simple, straightforward, and inexpensive method for changing current transformer ratios when they are actually connected into the circuit. The method enables the use of a single instrument for all motor ratings and a single transformer for all ranges within a given span of full load currents.

Instead of furnishing the instrument with a scale in amperes or watts, recourse has been had to the percent basis and the instruments are supplied with captions such as "Motor Load-Percent", "Percent Full Load", "Horsepower, %". Figure 1 shows a conventional a-c ammeter with a scale reading to 150%, and having a section from 125 to 150% in red as indicating a dangerous overload.

The safe allowable overload shown on the scale and which the motor will carry for a short period without damage, depends on the electrical and thermal overload

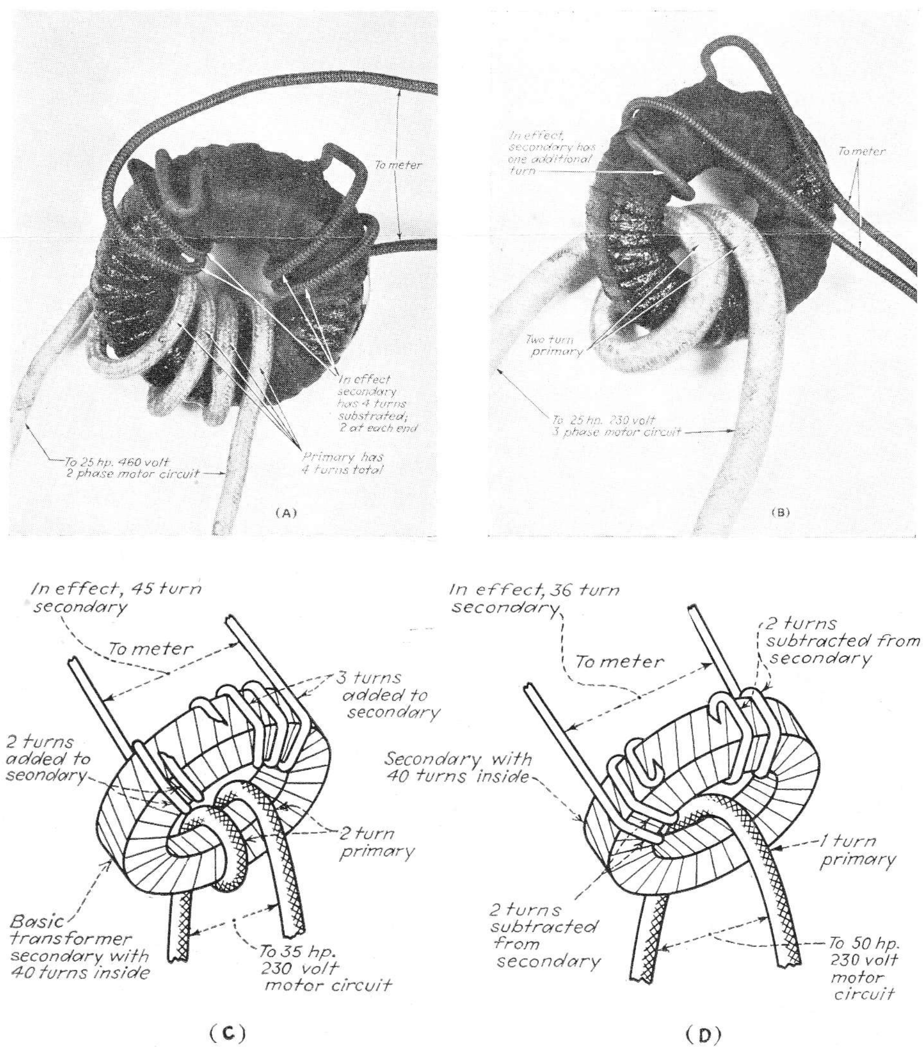


Figure 2—A special ring type current transformer provides adjustable ratios for the single rated instrument. (A) Doughnut transformer for 25 hp, 460 volt, two-phase motor of Table 1; only turns that pass through hole are effective. (B) Similar ring transformer for 25 hp, 230 volt, three-phase motor. (C) Five turns added for metering 35 hp, 230 volt, two-phase motor. (D) Four turns subtracted for metering 50 hp, 230 volt three-phase motor.

capacity of the motor and the operating cycle of the machine.

Adjustable Transformer Ratio

The single instrument for all motor ratings and sizes is made practicable by a single transformer that can be readily matched to the particular range of requirements for various motors. The transformer is a toroidal or ring type with a range near the highest current to be measured. For lower currents 2 or 3 turns of one of the motor leads are placed through the torus to give one-half or one-third of the original transformer primary current rating. For additional flexibility and to provide the intermediate values the secondary winding terminates in long flexible leads so that additional turns can be added. If fewer secondary turns are required, then turns can be wound in reverse, which effectively subtract from the main winding, as shown in Figure 2. In other words, the long leads provide an adjustment for matching the transformer ratio to a range of currents. Ampere turns in the primary must equal those in the secondary.

For example, assume a 200 to 5 transformer, supplying a 5 amp meter. To obtain full scale on the ammeter with 200 amp flowing in the single turn primary, the secondary will have 40 turns, disregarding a turn or a fractional turn for compensation. For 100 amp or half the previous line current, the primary requires 2 primary turns to produce the necessary 5 amp to give full scale reading on the ammeter.

Table I—Variations of 200/5 Normal Transformer Ratio for 25 Hp.

Voltage	Phase	100% Load, Amp.	150% Load, Amp.	Pri. Turns	Sec. Turns
230	3	68	102	2	+1
230	2	60	90	2	—4
460	3	34	51	4	+1
460	2	30	45	4	—4
575	3	27.2	40.8	5	+1
575	2	24	36	5	—4

Figure 2 shows the essence of the method in diagrammatic form as well as in actual photographs in a typical installation. It is to be noted that the leads are to be brought out of the transformer in such a way that it is quite obvious that when turns are added the winding is simply continued whereas, when turns are to be subtracted, the lead must be brought back on itself and a reversed turn placed around the core.

A Simple and Accurate Table

For simplicity and accuracy, a tabulation such as Table I is the usual way to show just how many turns to add or subtract. Similarly, tables for other horsepowers can be computed up to the current limit of the transformer. For example, a complete line of machines requiring from 5 to 40 hp motors and using a single size of meter and transformer, was tabulated for the various motors at all voltages to 550 volts, two and three phase.

Since many of the applications are for overload indication, the allowed error of two percent does not require precise transformer compensation. Also, normal voltage variations will make the translation from power to current somewhat approximate with ammeters, but the simplicity of the adjusted transformer method and its economic advantages seems to justify their use. Overloads of damaging degree are definitely indicated, and the accuracy is ample for many simple loads.

Where it is considered that the ammeter is not sufficiently representative of the true load, a single or polyphase wattmeter can just as readily be supplied scaled again on a percentage basis. The wattmeter, of course, is more costly than the ammeter, containing as it does two complete coil systems (four systems in a polyphase wattmeter) and the wiring is more complicated as shown at the right of Figure 3. Wiring complications are, in general, to be avoided where possible in the production lines of machine tools and other equipment using motors, and the utter simplicity of the ammeter connection, shown at the left of Figure 3, has much to recommend it where the ammeter indications are adequate for the purpose.

Although most industrial machines are supplied with a-c motors, if d-c power is used a d-c ammeter or wattmeter may be supplied in turn, only here the variable element will have to be a shunt. Shunts are not usually made adjustable in the field, but they are not unduly expensive and can generally be stocked in such ranges as required, all for use with a single indicating instrument with its percentage scale.

Instrument Guides the Operator

As an example of the problem and its solution, we have the application of an ammeter to heavy duty surface grinders which commonly use a separate motor di-

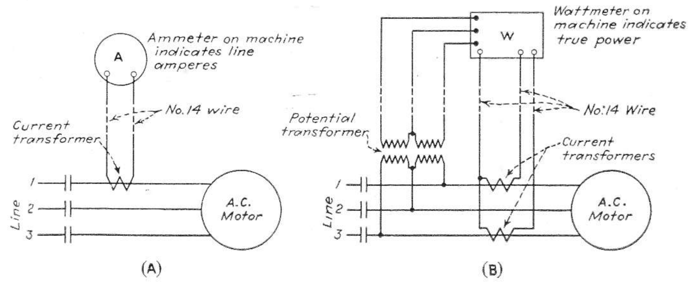


Figure 3—Typical connections for load indication. (A) Current transformer and ammeter. (B) Current transformers, voltage transformers and wattmeter.

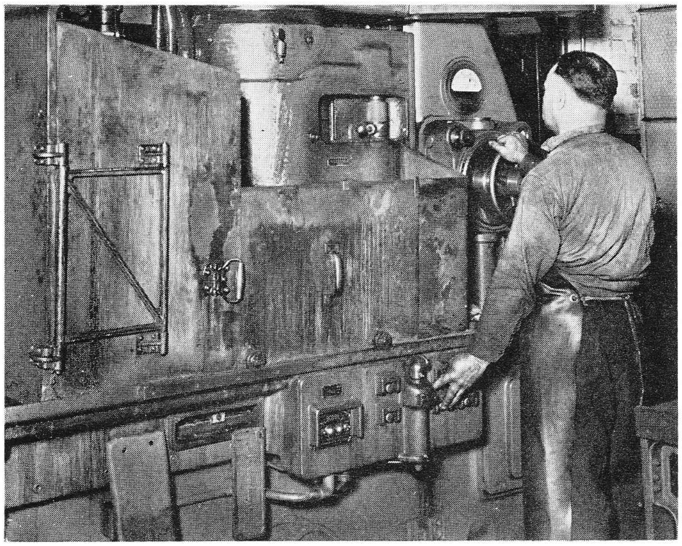


Figure 4—Peak machine capacity is obtained by operator using ammeter in spindle motor circuit to set grinder feed for optimum loading.

Blanchard Machine Co.

rectly driving the grinding wheel. As shown in Figure 4, the operator is adjusting the depth of cut on the basis of the current drawn by the grinding head motor.

When grinding on the full surface of the work the load on the spindle motor is ordinarily full load or more. Under the usual condition of using a wheel suitable for the full power of the machine, if too little power is used because of a shallow cut the wheel may glaze and refuse to cut. The ammeter guides the operator in adjusting rate of grinding to the correct feed and if his setting is incorrect he is warned by the increasing power that is consumed as the wheel begins to quickly glaze or dull. A wheel that is correctly matched to the work wears away fast enough to keep itself sharp and never requires dressing. However, even with the machine adjusted to the proper power consumption, if the wheel used is a little too hard it will gradually dull and require dressing. As the wheel slowly glazes, the corresponding increase in the ammeter reading lets an operator determine the most economical point in the operating cycle to redress the wheel for best overall production.

Optimum Operation

Instruments are also often used for optimum loading in mass production automatic machinery. For example, in operating heavy automatic screw machines there is always the problem of deciding at what point the tools should be resharpened or replaced. With a fixed cycle of tool feed for a given cut, the power and current increase as the tools become dull. On a given cut, experience dictates the optimum point for tool replacement. Once determined, the condition can be read on the meter, the machine shut down, and tools resharpened or replaced. Maximum production of uniform parts is secured with minimum rejections because of dull tools.

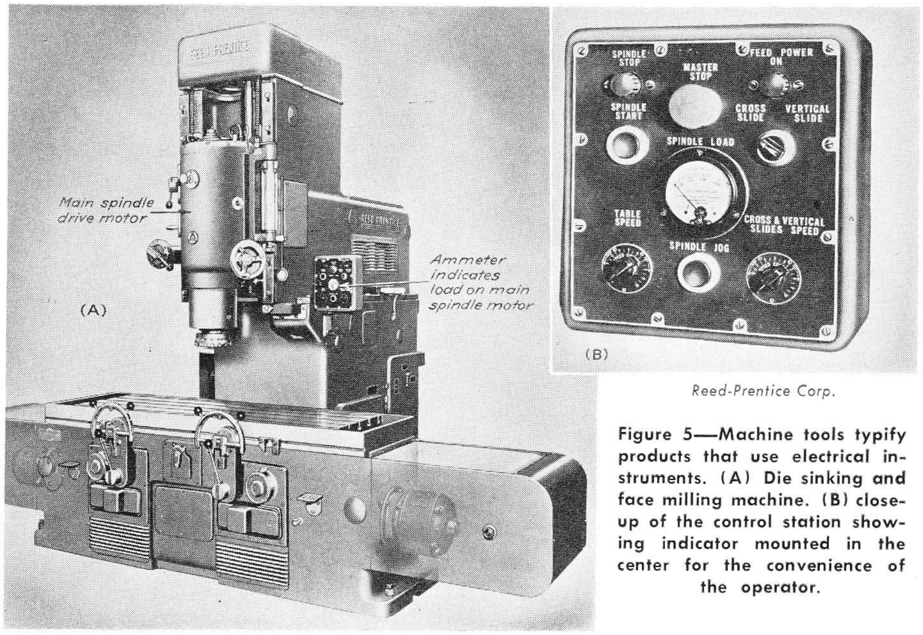
Another example of this type of installation is the vertical milling machine shown in Figure 5, that was designed especially for die sinking and face milling. An ammeter tells the operator at all times the load on the main spindle motor.

Many operators have little idea of the load they can place on a machine and so they rarely use it to capacity in order to be on the safe side. Also the instrument has proved to be good protection against overloading the machine. Although the machine has standard motor overload protection, when the overload relay stops the motor it usually breaks the cutter. This is particularly true when tungsten carbide cutters are used, therefore it is important that the motor is not stalled.

Instrument Dial Visible

Since the instrument dial must be visible to be useful, it is usually mounted on the machine near the operator and at some distance from the motor. The use of the current transformer, as explained, simplifies the wiring to the instrument because only relatively light #14 wires run to it. Further, one side of the current transformer can be grounded which brings the entire instrument to ground potential and completely eliminates any high voltage hazard should the glass be broken.

Instrumentation of machines will probably increase in the year or two ahead as industry swings



Reed-Prentice Corp.

Figure 5—Machine tools typify products that use electrical instruments. (A) Die sinking and face milling machine. (B) close-up of the control station showing indicator mounted in the center for the convenience of the operator.

into full scale peacetime production and low unit costs become increasingly significant. Also, by the proper integration of instruments into industrial machinery, designers can often substantially help the operator consistently utilize the optimum capacity that was so carefully designed into the machine. This produces maximum output with safety. The method of using a standard five ampere a-c ammeter with a percentage scale and an adjustable transformer will definitely help solve one of the industry's oldest problems, a simple and inexpensive way to control a-c motorized machines.

E. N.—No. 16 —*John H. Miller*

A METHOD OF PANEL MOUNTING WESTON MODELS 430-432-433

IN the building of test equipment for the production testing of vacuum tubes and small apparatus generally, numerous engineering groups appear to prefer the use of portable instruments with knife edge pointers and mirror scales. The wide distribution of Weston Model 430-432-433 instruments in laboratories has steered the thoughts of plant engineers to their use in such test panels.

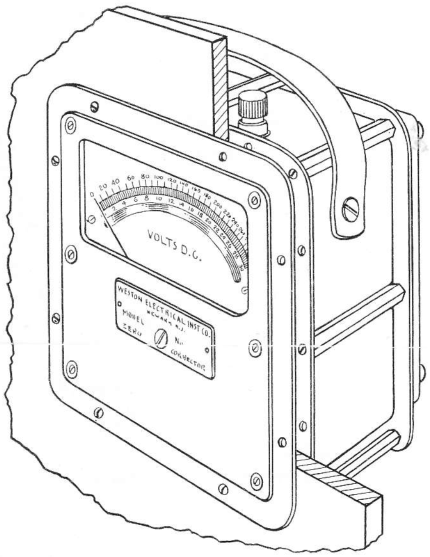


Figure 1—The instrument is clamped between two metal flanges and mounted in the panel with a third flange.

While such portable instruments are fundamentally designed for horizontal operation and are calibrated for use in this position, the fact remains that if carefully balanced they give excellent results when used vertically, provided that instruments of an ultra-sensitive type with very low torque are not so used. Even though we know that the fundamental accuracy cannot be attained in a vertical mounting and that friction effects may be present on the very sensitive instruments, the fact remains that instruments mounted vertically seem to be most acceptable in test panels. Many such installations are in actual use.

One of the problems in mounting portable instruments is to secure reasonably good appearance. It is no easy trick to file out a rectangular hole with suitable corner radii in a bakelite panel or, indeed, in an aluminum or steel panel, and perhaps this alone has been a deterrent to some mounting the instruments. To simplify this situation, our Drafting Room has worked out a design by means of which the instrument is clamped between a pair of metal flanges, and mounted in a panel with a third flange. The three flanges are identical except for the drilling. No changes are made on the instrument nor is any work done on it other than to remove the four rubber bumpers from the lower edges of the instrument; the bumpers are threaded in and can be removed with a pair of pliers. Even the leather handle is left in place, and the instrument can be returned to its normal use as a portable if the panel is torn down. See Figure 1. The panel may be of any thickness up to 3/8″ and the flange on the face serves both to clamp the instrument in place, as well as to cover any irregularities in the opening so that the aperture for the instrument can be cut out in a relatively rough manner and the assembly will still appear finished.

The aperture in the panel should be cut out to clear the inside flange dimensions shown, that is, 5.2″ high and 5″ wide. Corners can be square or made with a suitable drill. Eight holes for the mounting screws are needed as dimensioned for holes "A" in the sketch of the flange. See Figure 2.

The two body clamping flanges are held together with #5-40 flat head screws, 1/4″ long, threaded into the hexagonal posts, 16 screws being required. Eight #6-32 round head screws, 3/4″ long with suitable nuts and lockwashers serve to clamp the instrument to the panel with the third flange on the front. If one of the 8 posts between the two body flanges interferes with a terminal or a switch on the instrument that post can be omitted.

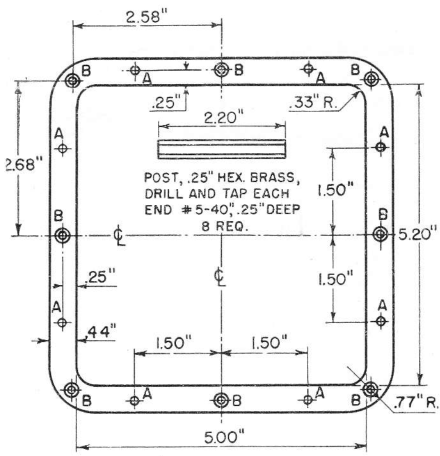


Figure 2—Details of flanges and posts. Front flange takes holes "A" only, middle flange holes "A" and "B", back flange holes "B" only. Holes, #25 drill. Holes "B" countersunk for #5 flat head screws. Flanges can be made of 1/16″ steel or brass.

During this period of reconversion and with requirements for tools for new items, it has not been possible to authorize tools for making these flanges and hence they are not stocked as standard parts. However, they are not difficult to cut out by hand. The flanges should be suitably rust-proofed and can be made from steel since they are sufficiently removed from the mechanism proper to avoid magnetic effects.

E. N.—No. 17 —*John H. Miller*